

United States Patent Application for:

**GAS DISTRIBUTION SHOWERHEAD
FOR SEMICONDUCTOR PROCESSING**

Inventor: Hamid Noorbakhsh

James D. Carducci

Jennifer Y. Sun


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1 [0001] **GAS DISTRIBUTION SHOWERHEAD FOR SEMICONDUCTOR**
2 **PROCESSING**

3 [0002] 1. **Field of the Invention**

4 [0003] The present invention pertains to a gas distribution showerhead assembly for use in
5 a semiconductor processing chamber.

6 [0004] 2. **Brief Description of the Background Art**

7 [0005] Semiconductor manufacturing processes utilize a wide variety of gases, such as
8 fluorine-based gases, chlorine-based gases, silanes, oxygen, nitrogen, organic gases (such as
9 hydrocarbons and fluorocarbons), and noble gases (such as argon or helium). In order to
10 provide uniform distribution of processing gases into a semiconductor processing chamber (such
11 as an etch chamber or a deposition chamber), a "showerhead" type gas distribution assembly
12 has been adopted as a standard in the semiconductor manufacturing industry. Several current
13 showerhead designs are summarized below.

14 [0006] U.S. Patent No. 5,451,290, issued September 19, 1995, to Salfelder, discloses a quartz
15 gas distribution plate containing a number of gas inlet holes having cross-sectional areas
16 sufficiently small to prevent plasma from being present in the gas inlet holes, to inhibit
17 formation of polymer material and flaking of contamination particles therefrom. The gas inlet
18 holes are formed on the surface of the quartz gas distribution plate directly over a wafer being
19 processed. Alternatively, the gas inlet holes are formed in the quart plate to radially extend to
20 the peripheral edge of the quartz plate, so that contamination particles are said to fall outside the
21 bounds of a wafer beneath the quartz plate. (Abstract)

1 [0007] U.S. Patent No. 5,614,026, issued March 25, 1997, to Williams, discloses a
2 showerhead designed to provide uniform distribution of process gas, where the showerhead
3 includes a plurality of gas inlets for supplying process gas to a semiconductor substrate surface,
4 and a plurality of gas outlets for removing gas and volatile byproducts produced as a result of
5 reaction of the process gas with the substrate surface. Each gas inlet is concentrically positioned
6 within a respective gas outlet. The showerhead is said to improve the utilization of process gas
7 species at the substrate surface by providing gas flow in a direction perpendicular to the
8 substrate surface and avoiding flow of the process gas or volatile byproducts laterally across the
9 substrate surface. The showerhead is said to be useful for uniform stripping of a mask of
10 organic material by direct contact of the incoming reactive gas with the substrate surface and
11 immediate removal of the process gas and volatile byproducts through the concentrically
12 arranged gas outlets. (Abstract)

13 [0008] U.S. Patent No. 5,781,693, issued July 14, 1998, to Ballance et al., discloses a
14 showerhead for use with a lamp head in a thermal processing chamber. The lamp head includes
15 a high intensity source which emits radiation that heats a substrate within the chamber. The
16 showerhead includes a top window on a side of the showerhead that is adjacent to the lamp
17 head; a bottom window on a side of the showerhead that is adjacent to the substrate during
18 processing; and a gas supply inlet through which a gas is introduced into a space between the
19 top and bottom windows, where the top and bottom windows are transparent to the radiation
20 from the source in the lamp head, and where the bottom window includes a plurality of gas
21 distribution holes through which gas is injected from the space between the top and bottom
22 windows into the chamber. (Abstract)

1 [0009] U.S. Patent No. 5,976,261, issued November 2, 1999, to Moslehi et al., discloses a
2 multi-zone gas injection apparatus which uses a gas injection plate with multiple injection zones
3 to deliver multiple process gases into a chamber for deposition onto a workpiece (for example,
4 a silicon wafer). The gas showerhead separates the multiple process gases in a manner that is
5 said to avoid premixing of the gases, thereby minimizing gas-phase nucleation and particulate
6 generation. The showerhead is said to allow real-time independent control over the gas flow
7 rates in N channels to achieve deposition uniformity. (Abstract)

8 [0010] U.S. Patent No. 6,050,506, issued April 18, 2000, to Guo et al., discloses a
9 showerhead used for dispensing gas over a wafer in chemical vapor deposition (CVD),
10 especially for CVD of metals. The pattern of holes is tailored to compensate for thermal and
11 other effects, in particular by increasing the density of holes toward the periphery of the wafer
12 in three or more zones. Such a variable pattern is said to be particularly useful for liquid
13 precursors that are atomized in a carrier gas, in which case a second perforated plate in back of
14 the showerhead face can be eliminated, thereby reducing the flow impedance and the required
15 pressure of the liquid-entrained gas, which tends to deposit out at higher pressures. (Abstract)

16 [0011] U.S. Patent No. 6,086,677, issued July 11, 2000, to Umotoy et al., discloses a
17 faceplate for a showerhead of a semiconductor wafer processing system having a plurality of
18 gas passageways to provide a plurality of gases to the process region without commingling
19 those gases before they reach the process region within a reaction chamber. The showerhead
20 contains a faceplate and a gas distribution manifold assembly. The faceplate defines a plurality
21 of first gas holes that carry a first gas from the manifold assembly through the faceplate to the
22 process region, and a plurality of channels that couple a plurality of second gas holes to a
23 plenum that is fed the second gas from the manifold assembly. (Abstract)

1 [0012] U.S. Patent No. 6,182,603, issued February 6, 2001, to Shang et al., discloses a
2 surface-treated showerhead for use in a substrate processing chamber. The showerhead includes
3 a surface treatment, such as a non-anodized aluminum outer layer, an electro-polished surface
4 of bare aluminum, or a fluorine-based protective outer layer. The surface-treated showerhead
5 is designed to improve the rate of removal of materials deposited on the interior surfaces of the
6 chamber during cleaning, reduces contamination of substrates during processing, and provides
7 more efficient use of the power source used for heating the substrate during processing.
8 (Abstract)

9 [0013] U.S. Patent No. 6,586,886, issued July 1, 2003, to Katz et al., discloses a gas
10 distribution plate electrode for a plasma reactor. The gas distribution plate includes a front plate
11 in the chamber and a back plate on an external side of the front plate. The gas distribution plate
12 comprises a gas manifold adjacent the back plate. The back and front plates are bonded
13 together, forming an assembly. The assembly includes an array of holes through the front plate
14 and communicating with the chamber, and at least one gas flow-controlling orifice through the
15 back plate and communicating between the manifold and at least one of the holes. The orifice
16 has a diameter which determines gas flow rate to the at least one hole. In addition, an array of
17 baffles (pucks) is at least generally congruent with the array of holes and disposed within
18 respective ones of the holes to define annular gas passages for gas flow through the front plate
19 into the chamber. Each of the annular gas passages is non-aligned with the orifice. (Abstract)

20 [0014] A cross-sectional schematic of one prior art showerhead assembly is shown in Figure
21 1A. The showerhead assembly 100 includes an electrode 104 and a gas distribution plate 102.
22 Figure 1B shows a top view of gas distribution plate 102. Numerous tiny through-holes 108 are
23 machined in gas distribution plate 102, through which various processing gases flow into a
24 semiconductor processing chamber (not shown). In order to prevent a plasma from igniting in

1 the through-holes 108, the holes typically have a diameter of about 0.020 inch or less (more
2 typically, about 0.010 - 0.015 inch). During semiconductor processing, polymeric contaminants
3 (by-products of etch or deposition processes) build up on the surface 110 of gas distribution
4 plate 102. These polymeric contaminants can flake off and contaminate a semiconductor
5 substrate (not shown) within the processing chamber. Therefore, when these polymeric
6 contaminants build up to a critical level (as determined by the semiconductor manufacturer),
7 the showerhead must be cleaned, resulting in chamber downtime and loss of productivity.

8 [0015] Polymeric contaminants typically do not build up inside through-holes 108 during
9 semiconductor processing, because of the process gases flowing through the holes 108 during
10 etch or deposition processes. However, during a cleaning process, these polymeric
11 contaminants can get pushed up into through-holes 108 and into the cavity 106 between gas
12 distribution plate 102 and electrode 104 (shown in Figure 1A). Like the through-holes 108, a
13 portion of cavity 106 typically has a diameter of about 0.020 inch or less, in order to prevent a
14 plasma from igniting in cavity 106. Once through-holes 108 and/or cavity 106 become filled
15 with contaminants, they can be extremely difficult to clean, because of their small size.

16 [0016] It would therefore be desirable to provide a gas distribution showerhead assembly
17 which could be easily cleaned, with minimal chamber downtime.

18
19 [0017] **SUMMARY OF THE INVENTION**

20 [0018] Disclosed herein is a gas distribution showerhead assembly for use in a
21 semiconductor processing chamber, such as an etch chamber or a chemical vapor deposition
22 (CVD) chamber. The gas distribution showerhead assembly of the invention includes an
23 electrode having openings therethrough, and a gas distribution plate which includes a plurality
24 of through-holes for delivering processing gases into the semiconductor processing chamber.

1 The gas distribution plate is attached (typically bonded) to a first, lower major surface of the
2 electrode.

3 [0019] The gas distribution showerhead assembly further includes a removable insert which
4 fits into an opening in the electrode through which gas flows. Spacing between surfaces of the
5 removable insert and surfaces of the electrode is adequate to permit gas flow, but inadequate for
6 plasma ignition within the opening. The removable insert may be a removable pin plate which
7 includes a plurality of pins. The removable pin plate is disposed over a second, upper surface
8 of the electrode in a manner such that the plurality of pins fit within the openings in the
9 electrode. A pin fills the majority of a space within the electrode. The removable pin plate is
10 in position, with the pins in place within the electrode openings, during use of the gas
11 distribution showerhead.

12 [0020] The removable pin plate can be easily removed from the second, upper surface of the
13 electrode during cleaning of the gas distribution showerhead. This permits the holes in the gas
14 distribution plate to be easily accessed from both sides of the gas distribution plate, so that any
15 contaminants that become entrapped in the holes of the gas distribution plate during a cleaning
16 process can be easily removed.

17 [0021] To prevent a plasma from igniting within the showerhead assembly during a
18 semiconductor manufacture processing procedure, the gap between the exterior surface of any
19 one pin and the electrode opening surface is typically 0.030 inch or less; more typically, 0.020
20 inch or less; and, most typically, within the range of about 0.010 inch to about 0.015 inch.

1 [0022] **BRIEF DESCRIPTION OF THE DRAWINGS**

2 [0023] Figure 1A is a cross-sectional schematic of a prior art showerhead assembly. The
3 showerhead assembly 100 includes an electrode 104 with cavities 106, bonded to a gas
4 distribution plate 102.

5 [0024] Figure 1B shows a top view of gas distribution plate 102. Numerous tiny through-
6 holes 108 are machined in gas distribution plate 102, through which various processing gases
7 flow into a semiconductor processing chamber (not shown).

8 [0025] Figure 2A is a cross-sectional schematic of one gas distribution showerhead assembly
9 200 according to the present invention, which is adapted for use in an Applied Materials'
10 eMAX™ etch chamber which is capable of processing 300-mm diameter substrate wafers
11 ("300-mm eMAX™").

12 [0026] Figure 2B shows a schematic of an expanded cross-sectional view of a portion of the
13 gas distribution showerhead assembly 200 shown in Figure 2A, which shows some of the
14 critical dimensions for various components of the showerhead assembly 200, which illustrate
15 how easily small openings could become plugged during cleaning if pins 246 were not
16 removable during cleaning. (All dimensions are in inches.)

17 [0027] Figure 2C shows a top view of gas distribution plate 208. The gas distribution plate
18 208 includes a total of 468, crescent-shaped through-holes 240, where the spacing between
19 walls of the crescent is about 0.010 inch. The crescent-shaped through-holes 240 are spaced
20 approximately 0.80 inch apart from each other.

1 [0028] Figure 2D shows an expanded, three-dimensional side view of a gas distribution
2 showerhead assembly 200, showing how the various components of the showerhead assembly
3 200 fit together.

4 [0029] Figure 3 shows a schematic of a cross-sectional view of a portion of a gas distribution
5 showerhead assembly 300 according to the present invention, which is adapted for use in an
6 Applied Materials' eMAX™ etch chamber which is capable of processing 200-mm diameter
7 substrate wafers ("200-mm eMAX™"). The 200-mm eMAX™ gas distribution showerhead
8 assembly 300 is very similar to the 300-mm eMAX™ gas distribution showerhead design
9 shown in Figure 2A.

10 [0030] **DETAILED DESCRIPTION OF THE INVENTION**

11 [0031] Disclosed herein is a gas distribution showerhead assembly for use in a
12 semiconductor processing chamber, such as an etch chamber or a chemical vapor deposition
13 (CVD) chamber, for example and not by way of limitation. The gas distribution showerhead
14 assembly of the invention includes an electrode having openings therethrough, and a gas
15 distribution plate which includes a plurality of through-holes for delivering processing gases
16 into the semiconductor processing chamber. The gas distribution plate is attached (typically
17 bonded) to a first, lower major surface of the electrode.

18 [0032] The gas distribution showerhead assembly further includes a removable insert which
19 fits into an opening in the electrode through which gas flows. Spacing between surfaces of the
20 removable insert and surfaces of the electrode is adequate to permit gas flow, but inadequate for
21 plasma ignition within the opening. The removable insert may be a removable pin plate which
22 includes a plurality of pins. The removable pin plate is disposed over a second, upper surface

1 surface of the electrode in a manner such that the plurality of pins fit within the openings in the
2 electrode. A pin fills the majority of a space within the electrode. The removable pin plate is
3 in position, with the pins in place within the electrode openings, during use of the gas
4 distribution showerhead.

5 [0033] The removable pin plate can be easily removed from the second, upper surface of the
6 electrode during cleaning of the gas distribution showerhead. This permits the holes in the gas
7 distribution plate to be easily accessed from both sides of the gas distribution plate, so that any
8 contaminants that become entrapped in the holes of the gas distribution plate during a cleaning
9 process can be easily removed.

10 [0034] As a preface to the detailed description, it should be noted that, as used in this
11 specification and the appended claims, the singular forms "a", "an", and "the" include plural
12 referents, unless the context clearly dictates otherwise.

13 [0035] The gas distribution showerhead assembly of the invention is described in detail
14 below with reference to Figures 2A - 2D.

15 [0036] Figure 2A is a cross-sectional schematic of a gas distribution showerhead assembly
16 according to the present invention, which is adapted for use in an Applied Materials' eMAX™
17 etch chamber which is capable of processing 300-mm diameter substrate wafers ("300-mm
18 eMAX™"). The showerhead assembly 200 includes outer gas plenum 202, inner gas plenum
19 204, a chill plate 205, an electrode 206, and a gas distribution plate 208. Processing gases flow
20 through outer gas feedthrough 210, through gas zone II diffuser 212, into outer gas plenum 202;
21 and through inner gas feedthrough 214, through lines 216 and 218, into inner gas plenum 204.
22 The inner and outer gas distribution zones are divided by gas zone divider 220, which is also
23 used for cooling gas distribution plate 208. The showerhead assembly 200 also includes high
24 efficiency cooling channels 222. The showerhead assembly further includes RF feedthrough

1 224 and matching network (not shown); iRM optical endpoint detection system 226; iRM
2 reflector mirror assembly 228; quartz optical window 230; and silicon carbide iRM window
3 232.

4 [0037] Figure 2B shows a schematic of an expanded cross-sectional view of the outer pin
5 plate 234, electrode 206, and gas distribution plate 208 of the gas distribution showerhead
6 assembly 200 shown in Figure 2A. The electrode 206 includes a plurality of through-holes 238.
7 The electrode 206 can be made of aluminum, ceramic, Si-Si carbide, or graphite converted to
8 silicon carbide, for example and not by way of limitation. In this case, the electrode 206 was
9 made of anodized aluminum. Anodized aluminum is particularly preferred because it reduces
10 metal contamination.

11 [0038] The gas distribution plate 208 can be made of silicon carbide, yttrium oxide, anodized
12 aluminum, ceramic, quartz, or silicon, for example and not by way of limitation. In this case,
13 the gas distribution plate 208 was made of silicon carbide. The gas distribution plate 208 was
14 bonded to a first, lower major surface 242 of electrode 206. Bonding of gas distribution plate
15 208 to electrode 206 was accomplished using a silicone-based adhesive with different types of
16 fillers tailored for enhancing thermal conductivity. Filler types include Al, Al_2O_3 , and boron
17 nitride. In this case, the silicon-based adhesive layer had a thickness within the range of 0.005
18 inch to 0.007 inch, and was cured at a temperature of about 100°C. The time period required
19 for curing of the adhesive will typically range from about 1 hour to about 12 hours; more
20 typically, from about 4 hours to about 12 hours. The curing time will depend on the particular
21 adhesive used and its recommended curing temperature. (For example, a higher curing
22 temperature will require a shorter curing time.) Suitable silicone-based adhesives are available,
23 for example and not by way of limitation, from Dow Corning (Midland, MI); Rhone-Poulenc
24 (France); and NuSil (Carpinteria, CA).

1 [0039] Bonding of gas distribution plate 208 to electrode 206 can be accomplished using
2 other materials and/or methods known in the art. However, bonding of gas distribution plate
3 208 to electrode 206 should be performed using a bonding material which has enough
4 compliance to prevent delamination due to thermal mismatch between the gas distribution plate
5 260 and the electrode 206.

6 [0040] Gas distribution plate 208 includes a plurality of through-holes 240 for delivering
7 processing gases into the interior of a semiconductor processing chamber. The through-holes
8 240 in the gas distribution plate 208 can be, for example and without limitation, round or
9 crescent-shaped. Crescent-shaped through-holes are preferred because they permit an increased
10 gas flow without possibility of plasma ignition in the through-holes 240. The spacing between
11 walls of the crescent is large enough to permit gas flow, but too small to permit plasma ignition
12 in the opening, and is typically less than about 0.020 inch; more typically, within the range of
13 about 0.010 inch to about 0.015 inch. The use of crescent-shaped through-holes in a gas
14 distribution plate for a showerhead assembly is described, for example, in commonly owned,
15 copending U.S. Application Serial No. 10/754,280, filed January 8, 2004, of Daniel Hoffman
16 et al., entitled "Plasma Reactor With Overhead RF Source Power Electrode with Low Loss,
17 Low Arcing Tendency and Low Contamination".

18 [0041] A removable pin plate (as shown in Figure 2A), which, in the 300-mm eMAX™ etch
19 chamber, comprises outer pin plate 234 and inner pin plate 236, is positioned above a second,
20 upper surface 244 of electrode 206 in a manner such that a plurality of pins 246, 247, extend
21 into through-holes 238 of electrode 206. The removable pin plates 234 and 236 can be made
22 of aluminum, ceramic, Si-Si carbide, or graphite converted to silicon carbide, for example and
23 not by way of limitation. In this case, the inner and outer pin plates 234 and 236 were machined
24 from aluminum, and then anodized to prevent aluminum contamination in the gas passages.

1 [0042] As illustrated in Figure 2B, the spacing 250 between the upper surface 244 of
2 electrode 206 and the lower surface 252 of pin plate 234 is typically within the range of about
3 0.010 inch to about 0.060. In this case, the spacing 250, which also assists in fluid control, was
4 0.040 inch.

5 [0043] The spacing between the bottom surface 248 of each pin 246 and the upper surface
6 249 of gas distribution plate 208 is typically within the range of about 0.010 inch to about
7 0.030 inch. In this case, the distance between the bottom surface 248 of each pin 246 and the
8 upper surface 249 of gas distribution plate 208 (which also assists in fluid control) was about
9 0.020 inch.

10 [0044] In order for process gases to flow from gas plenums 202 and 204 out through gas
11 distribution plate 208 and into the interior of a semiconductor processing chamber (not shown),
12 there must be gaps between the exterior surface 256 of each pin 246 and the surface 258 of the
13 electrode opening 238. The spacing 254 between the sidewalls 256 of each pin 246 and the
14 walls 258 of electrode 206 opening 238 is sized to prevent plasma from arcing into this space,
15 and is typically less than 0.030 inch; more typically, less than 0.020 inch; and, most typically,
16 within the range of about 0.010 inch to about 0.015 inch.

17 [0045] In the Applied Materials' 300-mm eMAX™ etch chamber, the electrode 206 includes
18 a total of 234 through-holes 238. The inner and outer pin plates 234, 236 together include a
19 total of 234 pins 246, 247, which fit into through-holes 238 of electrode 206. Figure 2C shows
20 a top view of gas distribution plate 208 which includes a total of 468 (two for each of the 234
21 through-holes and pins) crescent-shaped through-holes 240, where the spacing between walls
22 of the crescent is about 0.010 inch maximum. (The number of through-holes will depend on
23 the amount of gas flow needed.) The crescent-shaped through-holes 240 are spaced
24 approximately 0.80 inch apart from each other. In this case, the through-holes 240 were formed

1 in a silicon carbide gas distribution plate 208 by ultrasonic machining. The silicon carbide gas
2 distribution plate 208 has a thickness of 0.100 inch and a diameter of 14.23 inch.

3 [0046] Figure 2D shows an expanded, three-dimensional side view of a gas distribution
4 showerhead assembly 200, showing how the various components of the showerhead assembly
5 200 fit together. The outer and inner pin plates 234, 236 are attached to chill plate (lid) 205.
6 The pins 246, 247 of outer and inner pin plates 234 and 236 (respectively) fit into openings (not
7 shown in Figure 2D; indicated by reference numeral 238 in Figure 2B) in electrode 206. Silicon
8 carbide gas distribution plate 208 is typically bonded to aluminum electrode 206. Also shown
9 in Figure 2D are gas zone II diffuser 212; quartz optical window 230; and silicon carbide iRM
10 window 232.

11 [0047] Because the pin plates are attached to the chill plate (lid) 205, the pin plates can be
12 removed by removing the pin plate / lid assembly. Referring back to Figure 2B, removal of the
13 pin plate / lid assembly leaves the upper surface 244 of electrode 206 exposed for cleaning and
14 the openings 240 to gas distribution plate 208 exposed for cleaning as well.

15 [0048] Cleaning of built-up polymer on the exposed bottom surface 260 of gas distribution
16 plate 208 is typically performed by blasting the surface 260 of the silicon carbide gas
17 distribution plate 208 with dry ice (CO_2) to crack the polymer, followed by immersion of the
18 gas distribution plate and electrode in a solvent tank and ultrasonic cleaning bath. The solvent
19 composition within the solvent tank will depend on the materials from which the gas
20 distribution plate and electrode are made and on the contaminants expected to be present on the
21 surface of the gas distribution plate (which will depend on the particular gases and materials
22 used during processes performed within the chamber).

1 [0049] Typically, a pin plate / lid assembly which has been removed from the chamber is
2 replaced with a fresh pin plate / lid assembly, so that there is minimal downtime for the
3 processing chamber. The pin plate / lid assembly which has been removed can then be sent out
4 for cleaning and returned subsequently for further use.

5 [0050] When it is desired to use a plasma dry cleaning process for cleaning the chamber or
6 for cleaning the exterior of the gas distribution plate 208, the pin plate must be in place, with
7 pins 246 inserted into the openings 238 in electrode 206, in order to prevent a plasma from
8 igniting within the showerhead assembly during the cleaning process. Plasma cleaning of the
9 exterior of the showerhead assembly 200 can be performed using conventional methods known
10 in the art, which will depend on the materials from which components of the processing
11 chamber are made and on the contaminants expected to be present within the chamber (which
12 will depend on the particular gases and materials used during processes performed within the
13 chamber).

14 [0051] Figure 3 shows a schematic of a cross-sectional view of a portion of another gas
15 distribution showerhead assembly according to the present invention. The gas distribution
16 showerhead assembly 300 shown in Figure 3 is adapted for use in an Applied Materials'
17 eMAX™ etch chamber which is capable of processing 200-mm diameter substrate wafers
18 ("200-mm eMAX™"). The gas distribution assembly 300 shown in Figure 3 is similar in
19 design to the gas distribution assembly 200 shown in Figures 2A - 2D (which is adapted for use
20 in an Applied Materials' 300-mm eMAX™ etch chamber).

21 [0052] Showerhead assembly 300 includes a gas plenum 302, an electrode 306, a gas
22 distribution plate 308, and a removable pin plate 334. The electrode 306 includes a total of 133
23 through-holes 338.

1 [0053] The 300-mm e-MAX™ gas distribution showerhead assembly 200, shown in Figures
2 2A - 2D, included both an outer pin plate 234 and an inner pin plate 236. Due to its smaller
3 size, the 200-mm eMAX™ gas distribution showerhead assembly 300 includes a single
4 removable pin plate 334. The pin plate 334 includes a total of 133 pins 346, which fit into the
5 133 through-holes 338 in electrode 306.

6 [0054] The gas distribution plate 308, which is attached (typically bonded) to electrode 306,
7 includes a total of 266 (two for each of the 133 through-holes and pins) crescent-shaped
8 through-holes 340, where the spacing between walls of the crescent is about 0.010 inch
9 maximum. The crescent-shaped through-holes 340 are spaced approximately 0.80 inch apart
10 from each other. In this case, the through-holes 340 were formed in silicon carbide gas
11 distribution plate 308 by ultrasonic machining. The silicon carbide gas distribution plate 308
12 has a thickness of 0.100 inch and a diameter of 10.88 inch.

13 [0055] Unlike the 300-mm eMAX™ chamber, the pin plate 334 of the 200-mm eMAX™
14 chamber is not bonded to the chill plate / lid (not shown). The pin plate 334 can be removed
15 for cleaning by pulling it out after the chill plate / lid has been removed. No tools are required
16 for removal of the pin plate 334 from the 200-mm eMAX™ etch chamber.

17 [0056] The above described embodiments are not intended to limit the scope of the present
18 invention, as one skilled in the art can, in view of the present disclosure, expand such
19 embodiments to correspond with the subject matter of the invention claimed below.